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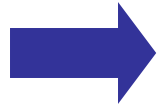
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## Objectives and Legal Requirements

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## ***Objectives***

Definition of processes, production and reliability testing of real products from different companies.

Study and compare the performance of different types of commercial solders with and without lead.

Achieve Benchmarking for lead and lead-free soldering

Support SMEs during implementation of Lead-Free Soldering in industrial processes.

Define/establish best practices in the production of several products using lead-free soldering

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## ***Legal Requirements***

RoHS – Restriction of the Use of Certain Hazardous Substances

Restictions to the use of some substances:

- ☐ Lead(0,1%)
- ☐ Mercury(0,1%)
- ☐ hexavalent chromium(0,1%)
- ☐ PBB (0,1%)
- ☐ PBDE (0,1%)
- ☐ Cadmium (0,01%)

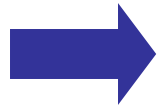
WEEE – Waste Electrical and Electronic Equipment Directive

- Regulate/stimulate the reuse, recycling and other forms of recovery of such wastes so as to reduce the disposal of waste

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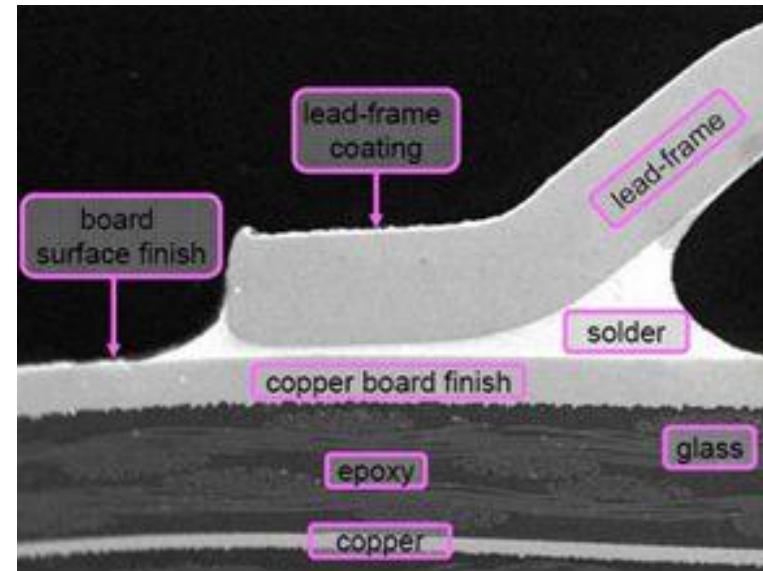
Future Work

# *Background*

## Components of an Printed Circuit Board

### Printed Circuit Board

- ☐ Board— Simple, Multi-layer, Flexible.
- ☐ Contact to Copper
- ☐ Terminal
- ☐ Finishing



# *Background*

## Components of an Printed Circuit Board

### Printed Circuit Board

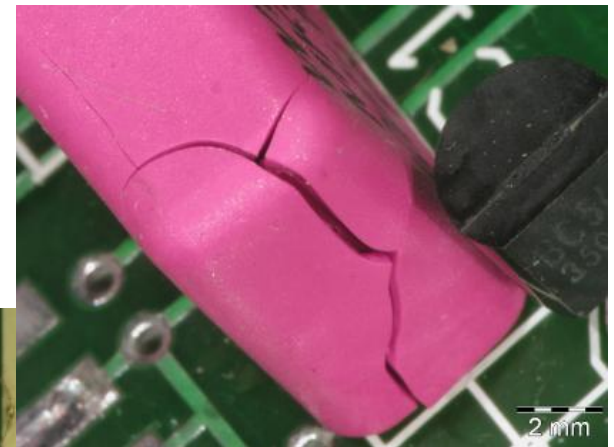
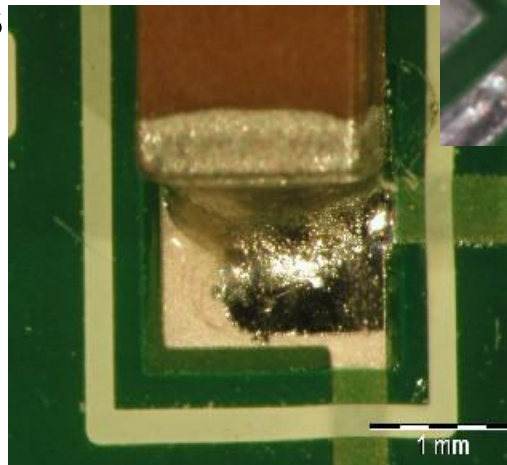
- ☐ Flux— Soluble in water(organic);  
resine based
- ☐ Solder— Lead:  $63\text{Sn}/37\text{Pb}$ ;  
 $62\text{Sn}/36\text{Pb}/2\text{Ag}$   
Lead-Free:  $96.5\text{Sn}/3\text{Ag}/0.5\text{Cu}$ ;  
 $96\text{Sn}/3.8\text{Ag}/0.7\text{Cu}$



# ***Background***

## **Problems with Lead-Free Soldering**

- ☐ Investment in Equipment's
- ☐ Thermal limitations and commercial availability of components and materials
- ☐ Flux compatibility
- ☐ Wettability





# ***Background***

## **Problems with Lead-Free Soldering**

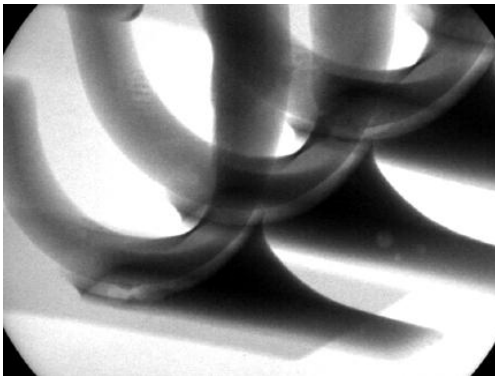
- ☐ Contamination
- ☐ Degradation of the tips of the soldering irons



# ***Background***

## **Problems with Lead-Free Soldering**

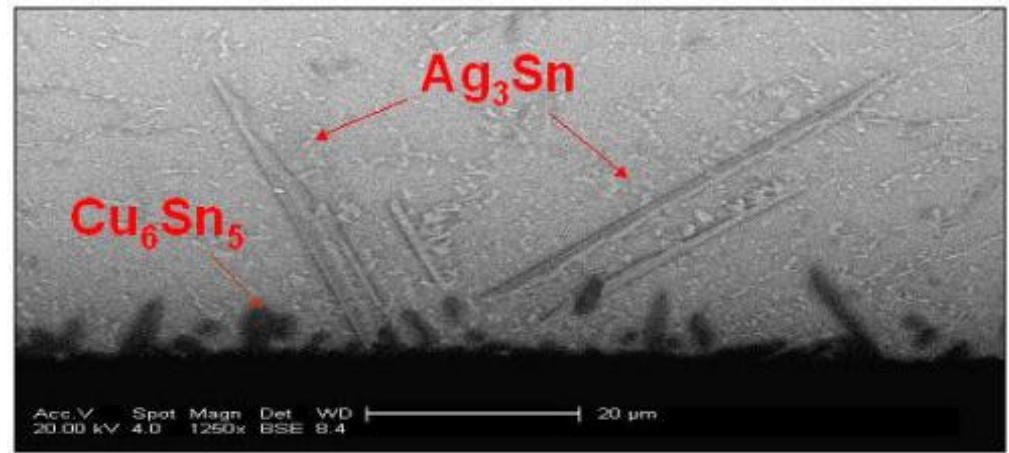
- ☐ Visual aspect of the joints
- ☐ Defects
- ☐ Reliability of the products



# Background

## Intermetallics

- ☐  $\text{Cu}_6\text{Sn}_5$
- ☐  $\text{Cu}_3\text{Sn}$
- ☐  $\text{Ag}_3\text{Sn}$



Hardness(HV0.2: GPa) -  $\text{Cu}_3\text{Sn}$  (5.5) >  $\text{Cu}_6\text{Sn}_5$  (4.6) >  $\text{Ag}_3\text{Sn}$  (1.4)

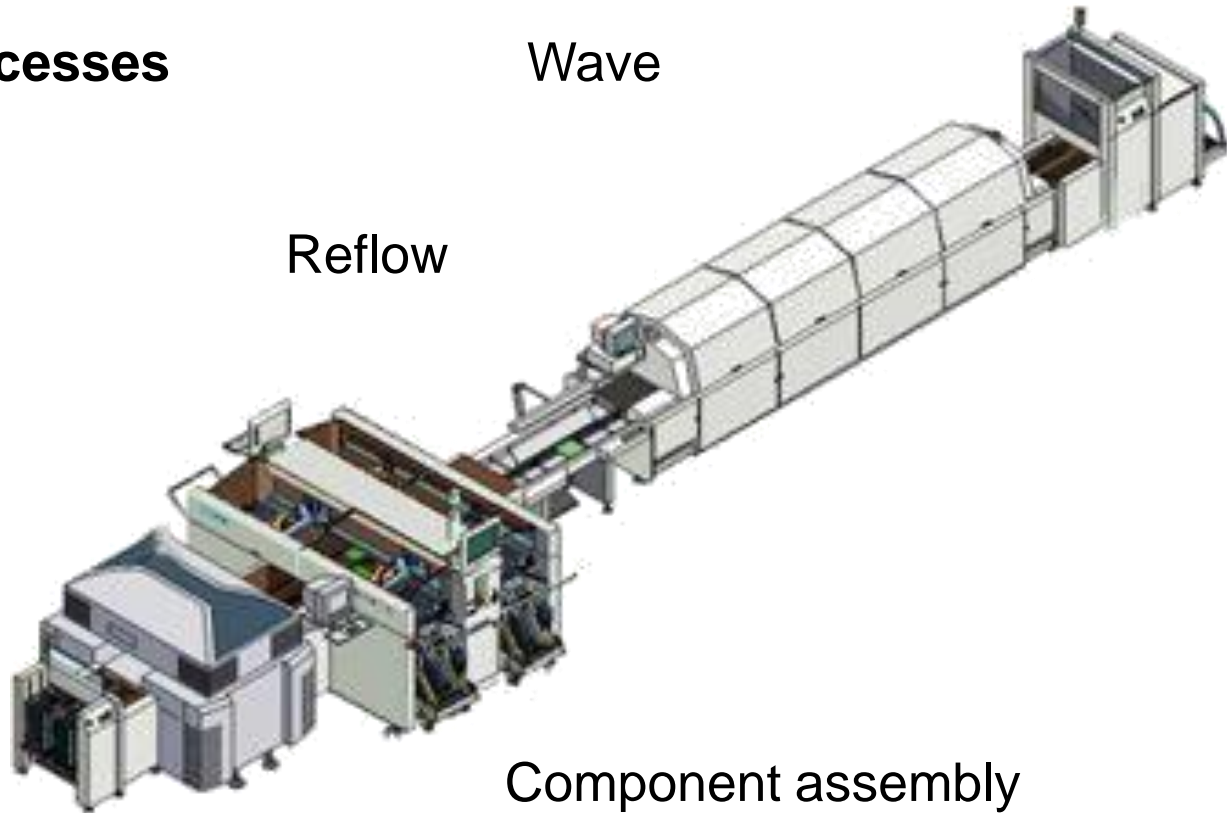
Young Module (GPa) -  $\text{Cu}_3\text{Sn}$  (152) >  $\text{Cu}_6\text{Sn}_5$  (57) >  $\text{Ag}_3\text{Sn}$  (55)

# ***Background***

**Main Welding Processes**

Wave

Reflow

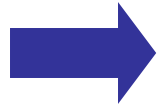


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## ***Developed Work***

The boards of 6 different companies were tested

### **Tests:**

- ☐ Reliability testing
- ☐ Functionality testing
- ☐ Characterizations of the boards before and after testing
  - Visual inspectionInspecção Visual
  - Optical Microscope
  - Scanning Electron Microscope (SEM)



## ***Developed Work***

Informations about the tested boards

Soldering:

With Lead: 63Sn/37Pb

60Sn/40Pb

62Sn/36Pb/2Ag

Lead-Free: Sn/Cu/Ni(SN100C)

96.6Sn/3Ag/0.5Cu

95.5Sn/3.8Ag/0.7Cu

Sn/Ag/Cu/Bi (SACX)

Temperatures:

250°C (Wave, Lead)

255 – 270°C (Wave, Lead-Free)

Processes:

Reflow

Wave

Manual

Componentes:

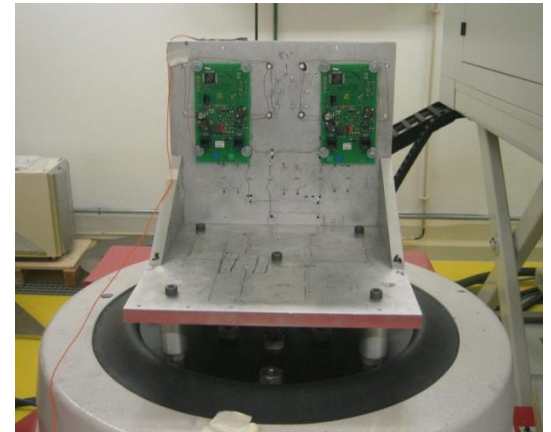
SMD – Surface  
Mount Device

Through-hole

## ***Developed Work***

### **Reliability testing:**

- ☐ Low Temperature Testing(72h; -40°C)
- ☐ High Temperature Testing (7 and 28 days; 100°C)
- ☐ Testing with thermal cycles(3000 and 6000h; 0 – 100°C)
- ☐ Thermal shock test -5 cycles; (-40/100°C)
- ☐ Vibration testing(30 min on each axis)
- ☐ Tensile testing(10s; 10N)





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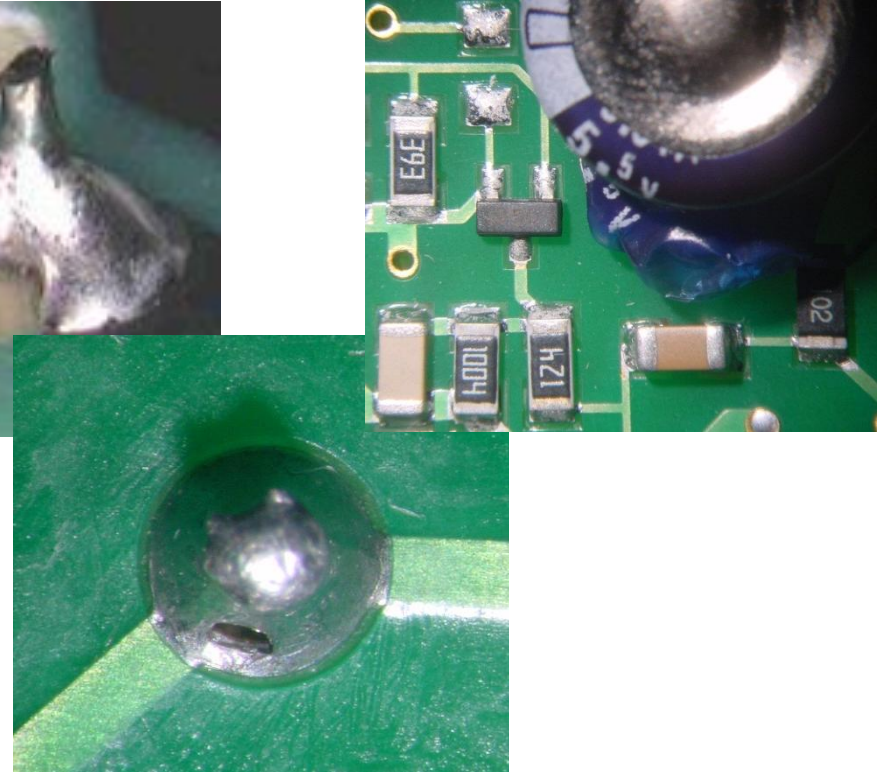
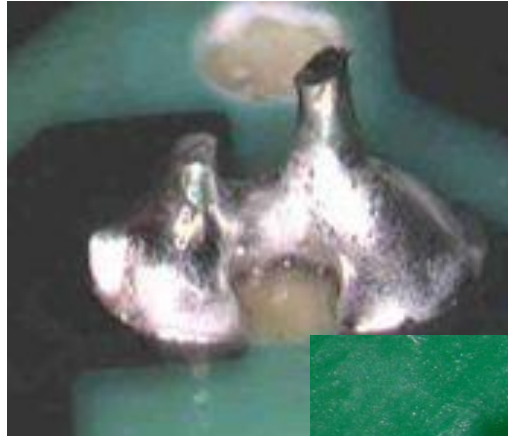
Future Work

# Results

## Visual Inspection

Before testing:

- ☐ Open Joint
- ☐ Solder balling
- ☐ Voiding
- ☐ Pad lifting
- ☐ Porosity



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# ***Results***

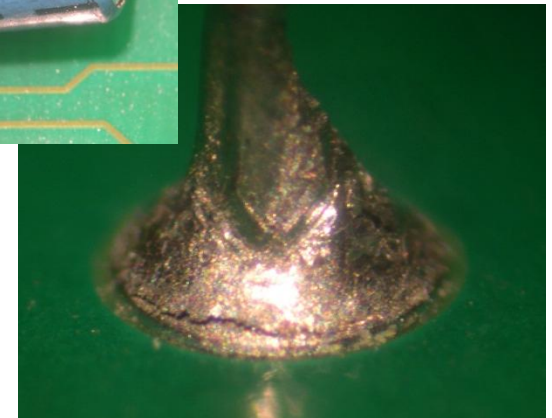
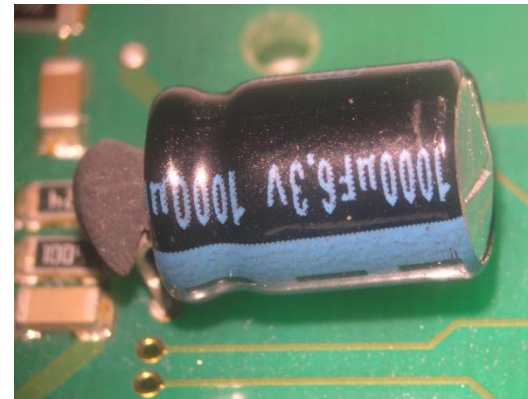
## **Visual Inspection**

After testing:

- ❑ Low temperature testing
  - 33% Sn/Pb e 0% LF did not pass the functionality tests
  - Without visible defects
  
- ❑ High temperature testing
  - 50% Sn/Pb e 27% LF did not pass the functionality tests
  - Componentes failure

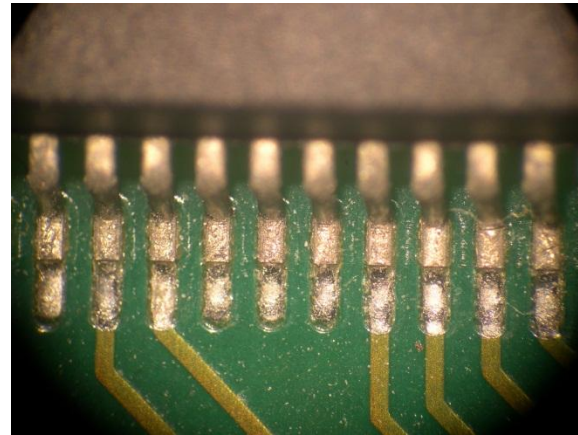
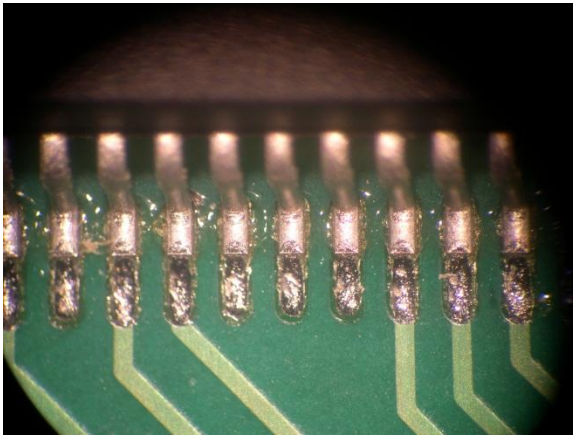
# Results

- ❑ Thermal cycling test
  - 59% Sn/Pb e 49% LF did not pass the functionality tests
  - Componentes failure
  - Cracks in the joints
  - Damaged components
  - Degradation



## ***Results***

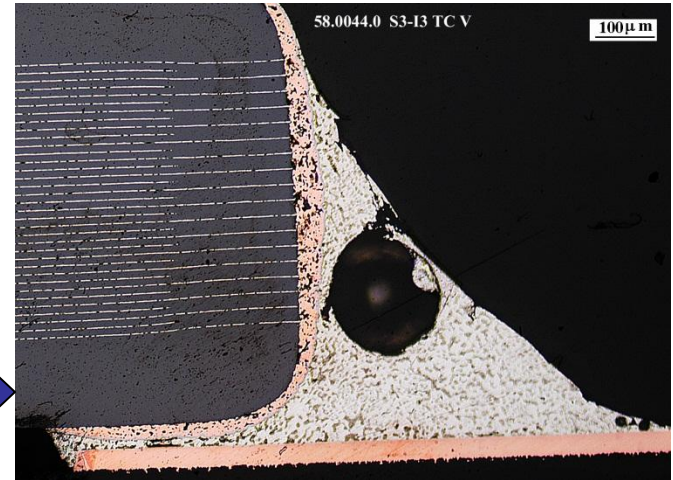
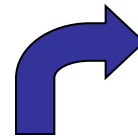
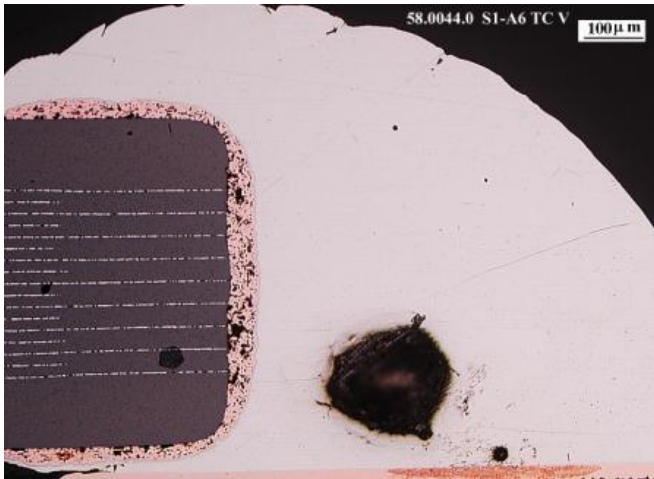
- ❑ Thermal shock test
  - 0% Sn/Pb e 11% LF did not pass the functionality tests
  - Without visible defects
- ❑ Vibration tests
  - All the boards have passed in the electrical functional test



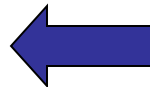
# Results

## Optical Microscope

### ❑ Voids



Board C, Reflow, 62Sn/36Pb/2Ag,  
Thermal Cycles



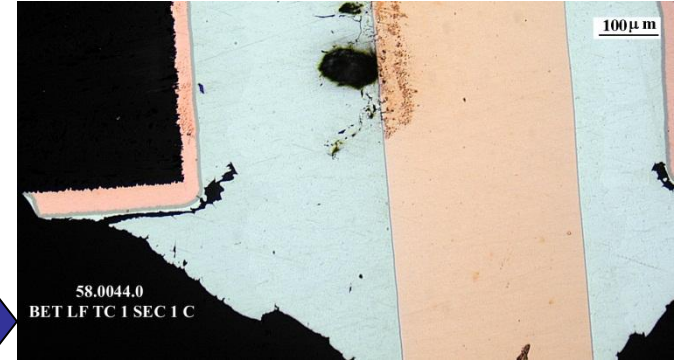
Board E, Wave, 96.5Sn/3Ag/0.5Cu,  
Thermal Cycles



# Results

## Optical Microscope

### ❑ Cracks



Board F, Wave, Sn/Ag/Cu/Bi, Thermal Cycles

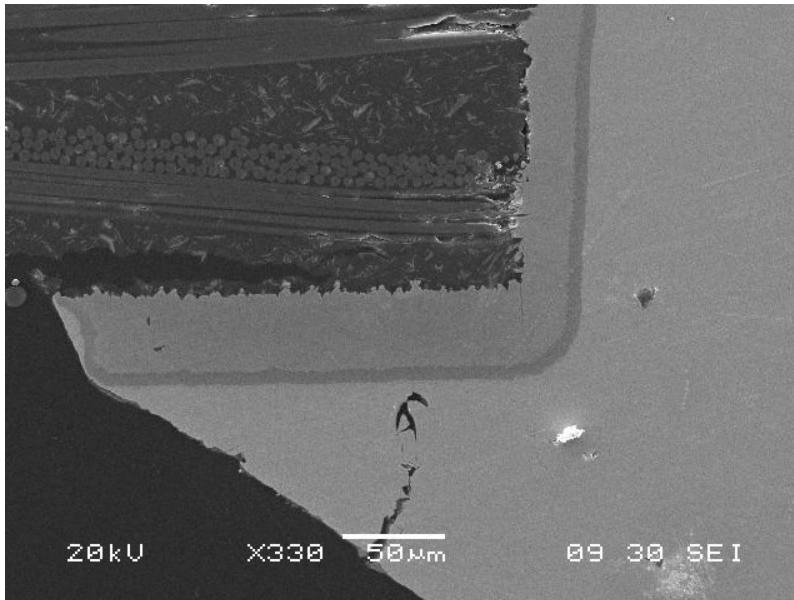
Board E, Wave, 96.5Sn/3Ag/0.5Cu, Thermal Cycles



# Results

## Scanning Electron Microscope (SEM)

- ❑ Lift of the contact with the board

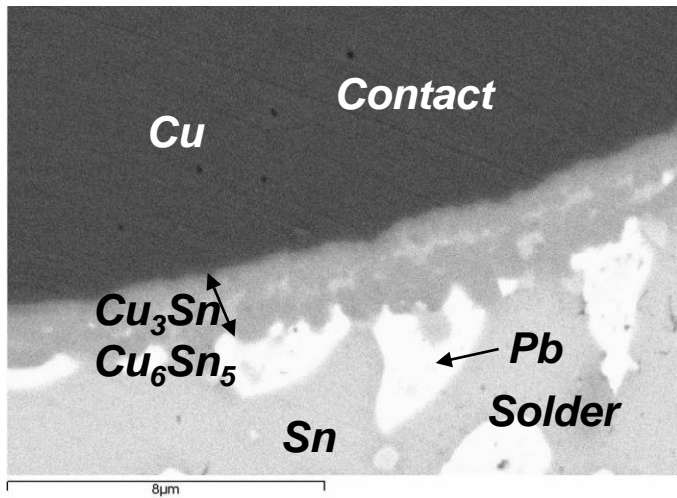


<i><b>Material</b></i>	<i><b>CET (x10<sup>-6</sup>/K)</b></i>
<i>Sn</i>	<i>23.5</i>
<i>Ag</i>	<i>18.9</i>
<i>Cu</i>	<i>17</i>
<i>Ni</i>	<i>13</i>
<i>Pb</i>	<i>29</i>
<i>Cu<sub>3</sub>Sn</i>	<i>18.4</i>
<i>Cu<sub>6</sub>Sn<sub>5</sub></i>	<i>20</i>
<i>Laminated</i>	<i>17</i>

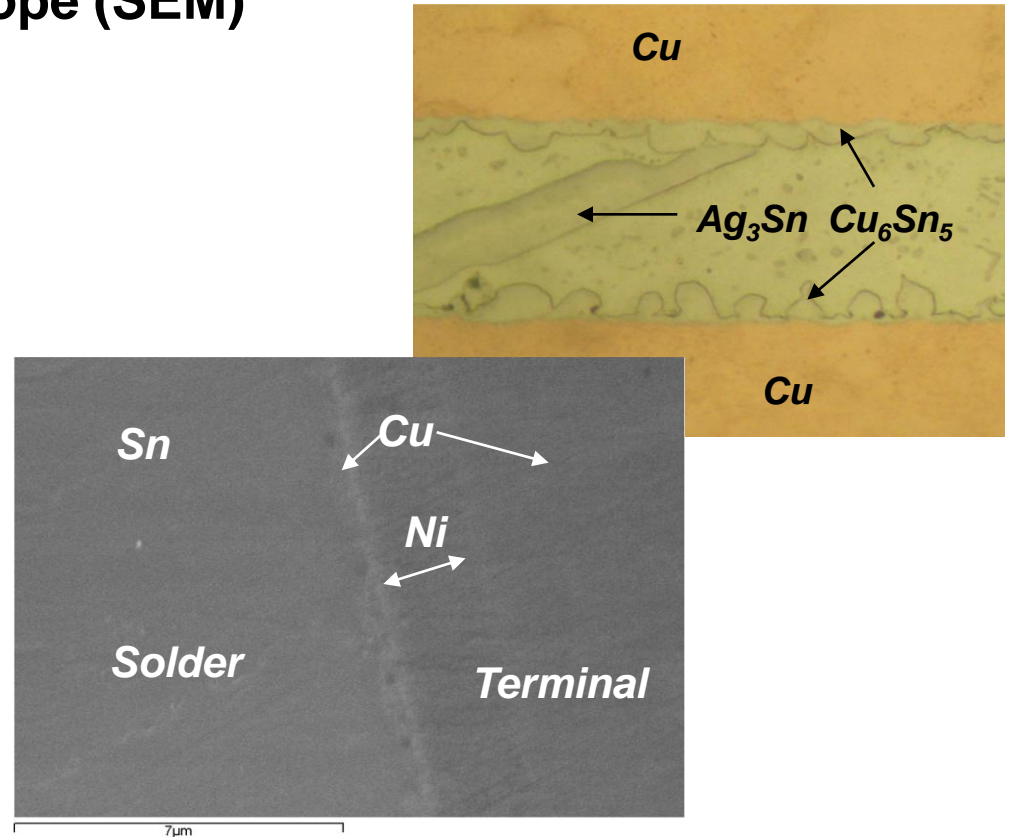


# Results

## Scanning Electron Microscope (SEM)



Micro Structures



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## ***Conclusions***

- ❑ No major difficulties in LFS process
- ❑ Wave process with higher defect level in the transition
- ❑ Due to corrosion inhibitors, SACX solder showed negative results
- ❑ Detected defects(voids and pad lifting) are common in these assembling processes due to lack of pre-heating or inadequate thermal cycles
- ❑ Most of the samples had a good reliability, except in thermal fatigue tests.

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## ***Conclusions***

- ❑ SMD had lower damage level than “through-hole” samples and mainly due to the assembling process.
- ❑ Cracking on “through-hole” samples are far from the interface, without significant propagation, showing good results in both Pb/Sn and LFS joining.
- ❑ Most of the defects can be avoided and do not introduce integrity and functionality risks .
- ❑ Damage in Pb-Sn and LFS are similar
- ❑ In general LFS samples showed good performance

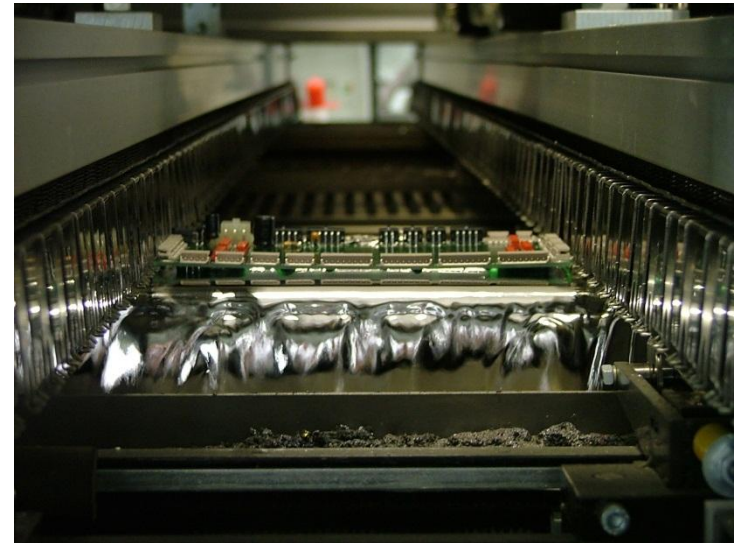
# ***Conclusions***

## **Using best practices**

- ❑ Reflow
  - Pre-heating temperature
  - Thermal profiles
  - Cost benefit analysis

### Wave

- Pre-heating temperature
- Temperature
- Containers/tanks
- Cost benefit analysis



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# ***Conclusions***

## **Cost benefit analysis:**

- ❑ Costs
  - Equipments
  - Components and PCI
  - Pastes
  - Energy
  - Training
  
- ❑ Results
  - Defect Level
  - Reliability
  - Production

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## ***Future Work***

- ☐ Components must be adequate to the temperature
- ☐ High reliability of solders (new alloying elements, nano-particles)
- ☐ New Inspection Methods (MICROFOCUS)
- ☐ Increase the quality of Soldering Processes
- ☐ Use of Laser for small batches
- ☐ Modelling and validation of soldering processes
- ☐ Reliable reuse of components
- ☐ Networking (SOLDERTEC, NPL, EUROSIME)





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# ***Acknowledgements***

Dag Andersson – IVF

Simon Mason -TWI

Bob Willis - SMART Group

***Thank You!***